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Scott Polar Research Institute
University of Cambridge

Advanced Approach to Mapping Human Impact on Vegetation of the European North

Ekaterina Shipigina & Gareth Rees

Scott Polar Research Institute,
University of Cambridge

es377@cam.ac.uk & wgr2@cam.ac.uk

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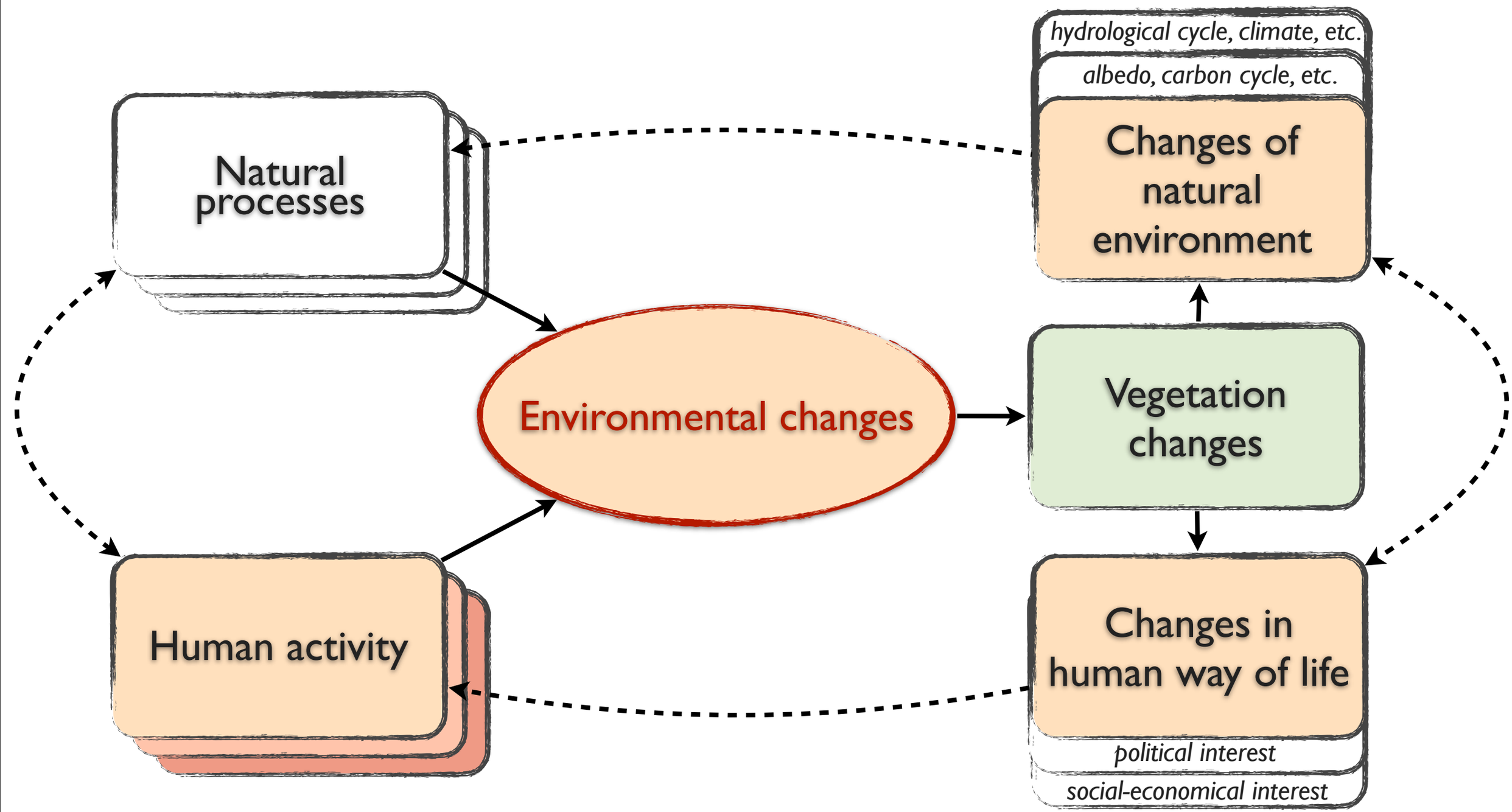
Background

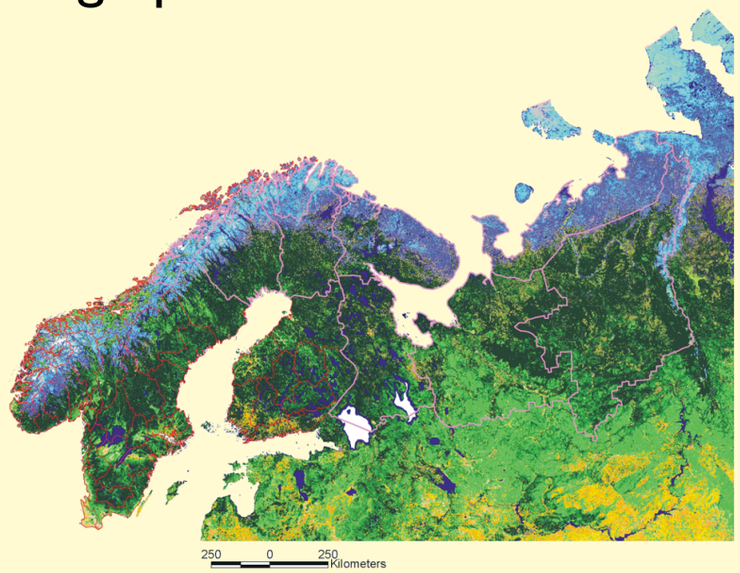


? Relationship between human impact on vegetation and the response of vegetation on local, regional and global scales

Research subject: treeline in Northern Europe

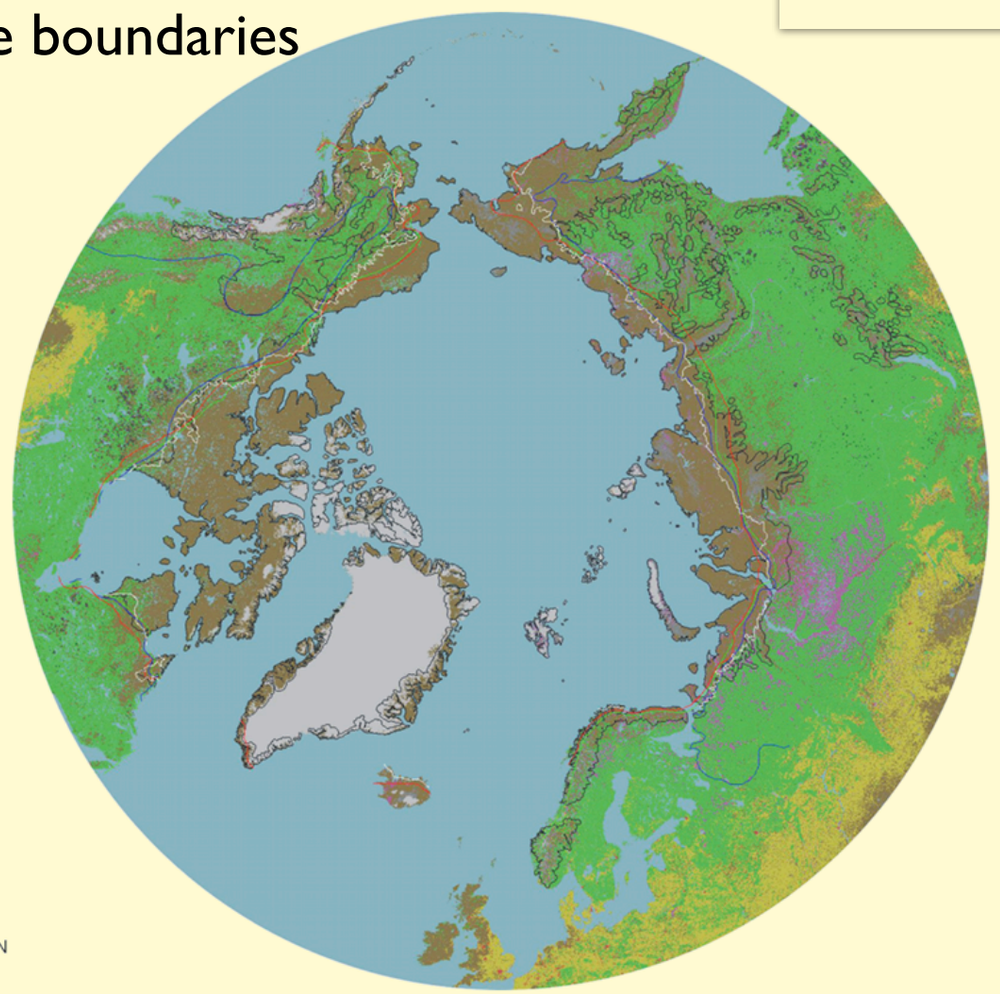
- Most industrially developed region of the Arctic and Sub-Arctic
- Significant human impact on its vegetation in forest, pre-tundra and tundra zones
- Possibly a link between human activity and the position and structure of treeline

Geographical zones



Study area

Tree boundaries



Hustich, 1983:
- birch;
- evergreen conifer;
- larch.

- CAVM, 2003
- Olson&Dinerstein, 1998

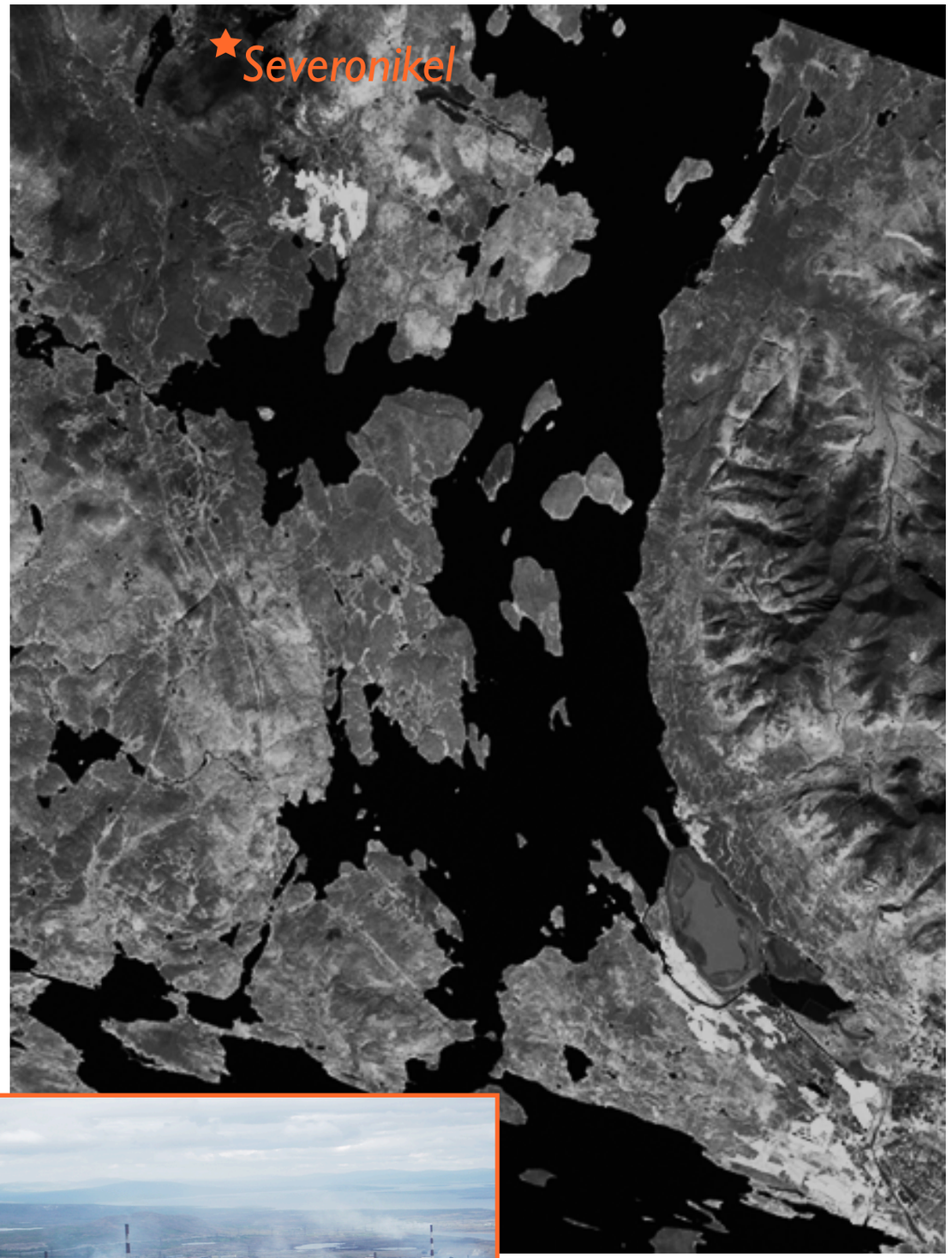
Test hotspots for human impact

Types of human impact:

1. Industrial atmospheric pollution (Monchegorsk and Nikel, Russia);
2. Fire (Monchegorsk and Kandalaksha, Russia);
3. Mining extraction, urbanisation/ infrastructure (Zapolyarniy, Russia; Kiruna, Sweden; settlements);
4. Grazing (Finnmark, Norway and Lapland, Finland);
5. Logging (Kovdor, Russia; Lapland, Finland).

Test hotspot: Monchegorsk area

Landsat elp186r013_7t20000728, 28 July 2000, zone 4



- Copper-nickel 'Severonikel' smelter
- Heavily industrialised in forest geographical zone
- Emissions of sulphur dioxide and heavy metals have adverse effect on physiological processes of plants
- Transported over long distances, accumulate and migrate in the ecosystem's components

Impacts expected:

- Severe forest/tundra damage through atmospheric emissions
- Forest fires
- Infrastructure build-out
- Water pollutions (outside of this research)

Automated classification of Landsat data

Idea

- Using training data from a number of Landsat images perform automated classification of any further Landsat images

Prerequisites

- Comparability of data (atmospherically corrected)
- Automation of atmospheric correction
- Scripting execution (no manual intervention)

Benefits

- Reproducibility and objectiveness of the analysis and comparisons
- High throughput
- Possibility for automated monitoring of changes

Use of free and open source tools

- Availability of tools to a wide research audience
- Reproducibility of the analysis by third party

Implementation details

Atmospheric correction and conversion of spectral radiance to normalised reflectance

- input: Landsat images & Landsat metadata ONLY
- dark pixel cut-off: 0.02 percentile of the histogram
- calculation according to Markham&Barker[1]

Classifier

- Support Vector Machines[2] (SVM)

Software development (outsourced)

- scripting: R language[3] (for statistical computing, FOSS*)
- image manipulation: ImageMagick & geotiff libraries (FOSS)

1) **Atmospheric correction:** Markham, B. and Barker, J. (1986) 'Landsat MSS and TM post-calibration dynamic ranges, exoatmospheric reflectance and at-satellite temperatures'. *EOSAT Technical Notes*.

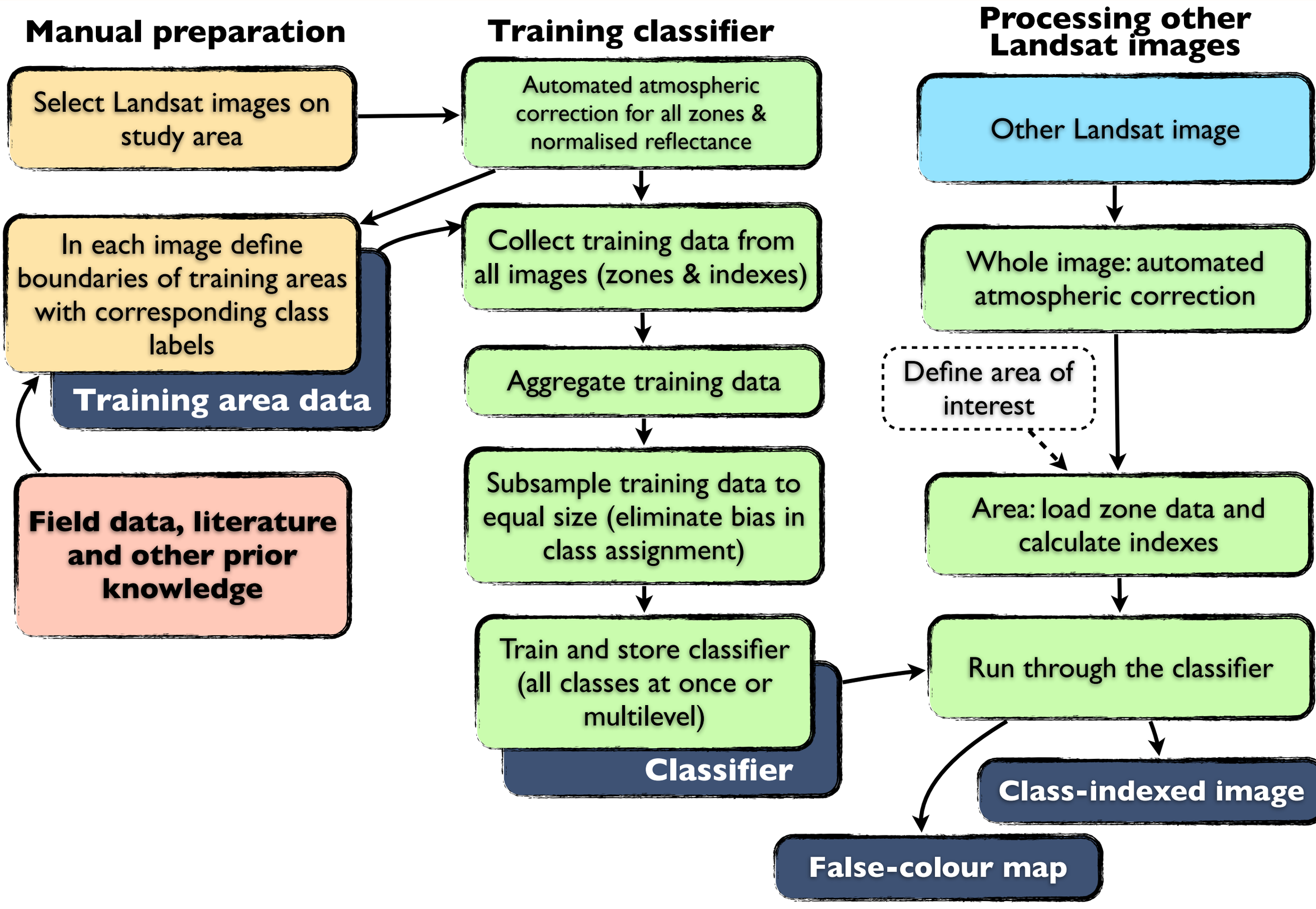
2) **Support Vector Machines** (SVM)**:**
   - Developed primarily by V. Vapnik between 1963 and 1995, e.g. V. Vapnik *Estimation of Dependences Based on Empirical Data* 2nd Ed., 2006, Springer (http://books.google.co.uk/books?id=DeaPEwUW_TAC&printsec=frontcover)
   - Comparison to 16 other classifiers: David Meyer, Friedrich Leisch, and Kurt Hornik. *The support vector machine under test.* Neurocomputing 55(1-2): 169-186, 2003 (http://dx.doi.org/10.1016/S0925-2312(03)00431-4)

3) **R language:** http://www.r-project.org

4) **ImageMagick** (http://www.imagemagick.org); **GeoTIFF** (http://geotiff.osgeo.org)

*) **FOSS:** free and open source

Automated classification workflow-chart



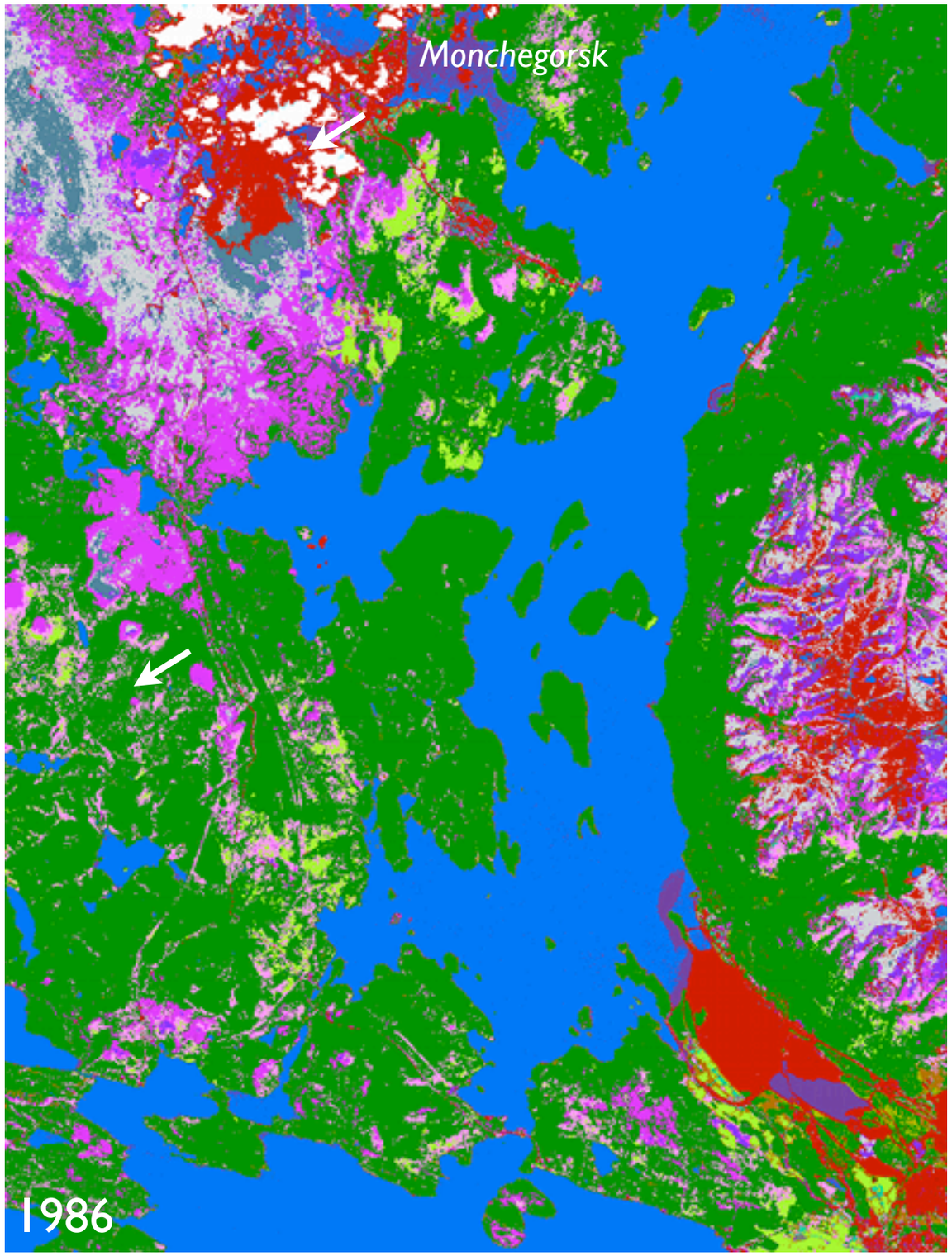
Class diagram (this presentation: top level only)

- **snow_group:**
  - snow
- **cloud_group:**
  - cloud
- **water_clean:**
  - deep_water
- **water_polluted:**
  - industrial_water
  - water_with_sand
  - very_wet_tailing_pond
- **natural_forest_coniferous_undamaged:**
  - forest_undam_pine_with_dwarf_shrub
  - forest_undam_pine_with_dwarf_shrub_and_lichen
  - forest_undam_pine_with_dwarf_shrub_and_moss_and_lichen
  - forest_undam_pine_with_lichen
  - forest_undam_spruce_with_dwarf_shrub
  - forest_undam_spruce_with_moss_and_lichen
  - forest_undam_spruce_with_dwarf_shrub_and_lichen
  - forest_undam_spruce_with_dwarf_shrub_and_lichen_and_moss
  - forest_undam_spruce_with_moss_lichen_and_birch
- **natural_forest_deciduous_undamaged:**
  - forest_undam_birch_and_willow_forest_along_rivers
  - forest_undam_birch_with_grass_and_dwarf_shrub
  - agricultural_field_grass_birch_willow
  - forest_undam_birch_shrub_in_mountain
- **natural_forest_mixed_undamaged:**
  - forest_undam_pine_birch
  - forest_undam_pine_spruce_with_dwarf_shrub
- **wetland:**
  - wetland_fen_and_carex_marches
  - wetland_with_dwarf_shrub_and_open_water
  - wetland_with_dwarf_shrub_moss_grass
  - wetland_with_dwarf_shrub
  - drainage_wetland
- **natural_forest_tundra_zone_undamaged:**
  - forest_undam_birch_shrub_with_dwarf_shrub_and_lichen_land
  - forest_undam_birch_shrub_with_lichen_land
  - forest_undam_grass_dwarf_lichen_in_land
- **natural_tundra_undamaged:**
  - tundra_undam_dwarf_shrub_lichen_tundra
  - tundra_undam_lichen_dwarf_shrub_tundra
  - tundra_undam_lichen_tundra
- **natural_non_vegetated_undamaged:**
  - tundra_stone_tundra
- **human_non_vegetated:**
  - asphalt
  - quarry
  - spoil_heap
  - residential_area
  - dry_tailing_pond
  - wet_tailing_pond
- **human_forest_techno_barren_damaged:**
  - forest_technogenic_barren_with_no_vegetation
  - forest_technogenic_barren_almost_with_no_vegetation
- **human_forest_severely_damaged:**
  - fire_impact:
    - new_burnt_area
  - emmission_impact_severely_damaged:
    - forest_severely_damaged
    - forest_severely_damaged_in_birch_shrub
- **human_forest_moderately_damaged:**
  - emmission_impact_moderately_damaged:
    - forest_moderately_damaged_birch_forest
    - forest_moderately_damaged_spruce_forest
    - forest_mostly_damaged_birch_spruce
  - logging_impact:
    - clear_cutting_area_lapland
    - clear_cutting_area_with_birch_kiruna
    - clear_cutting_area_with_lichen
    - clear_cutting_area_with_lichen_and_birch_kovdor
    - clear_cutting_with_subsoil_ploughing
  - grazing_impact:
    - tundra_grazing_shrub_lichen_tundra
- **human_tundra_damaged:**
  - tundra_techogenic_barren_tundra

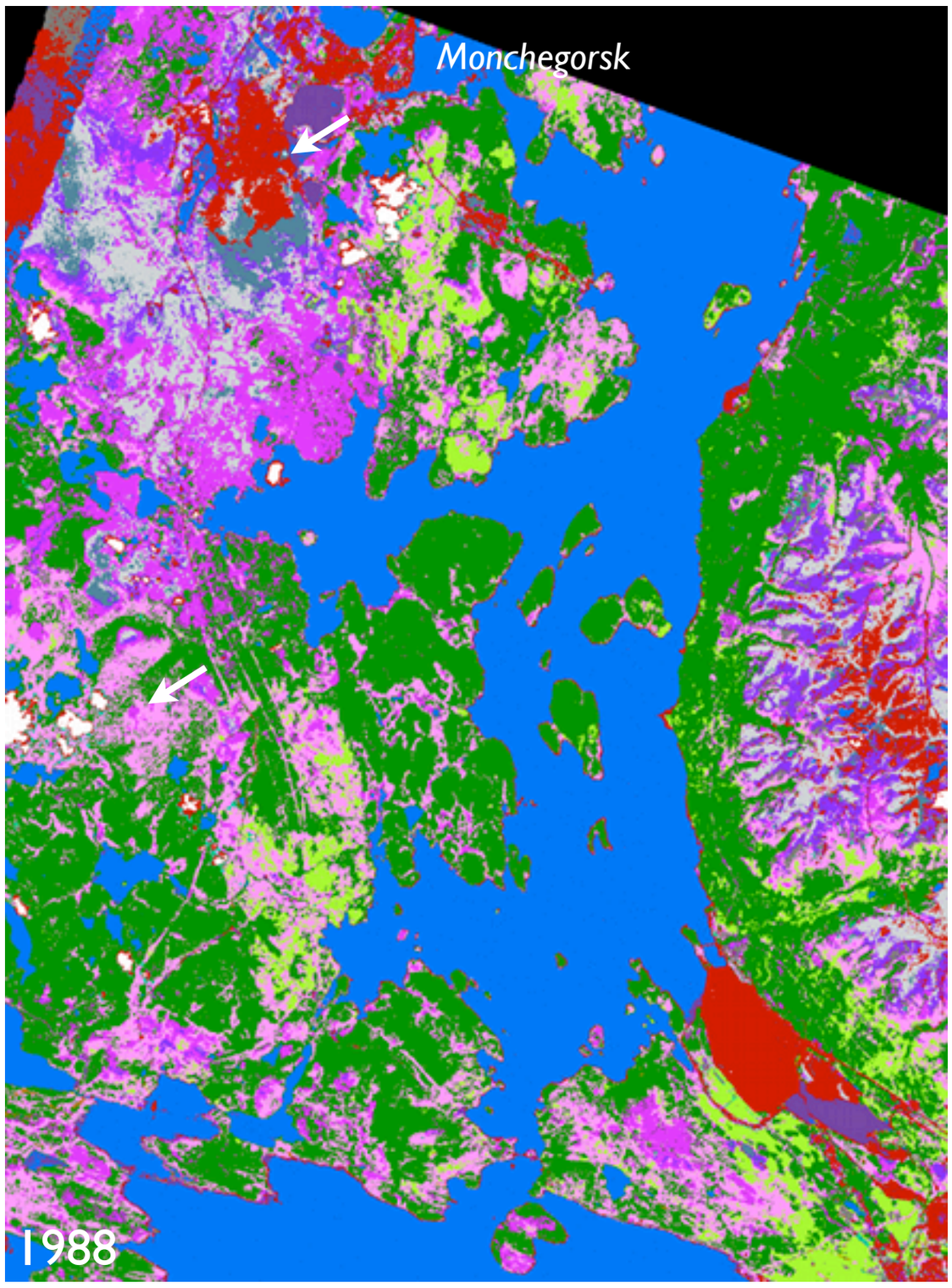
Comparision of classification approaches

Software	R	Erdas Imagine
Classification technique	Support Vector Machines (any other classifier)	Maximum likelihood
Access to software	Free and open source	Commercial
Access for third parties	Easy	Limited, due to licenses
Ease of making corrections to training data	Yes	No
Time for full image processing per image	Very quick, minutes	Not quick, at least 1 day
Quality of classification results	Good	Easy to miss classes
Condition for the good classification results	High quality training data, defining once for all images	High quality training data, defining for each image, deep knowledge of the area
My expert feelings about usage of classification	Excellent, requires generic scripting knowledge	Takes time, requires specific Erdas knowledge

Results: monitoring ecosystem 1986-1988

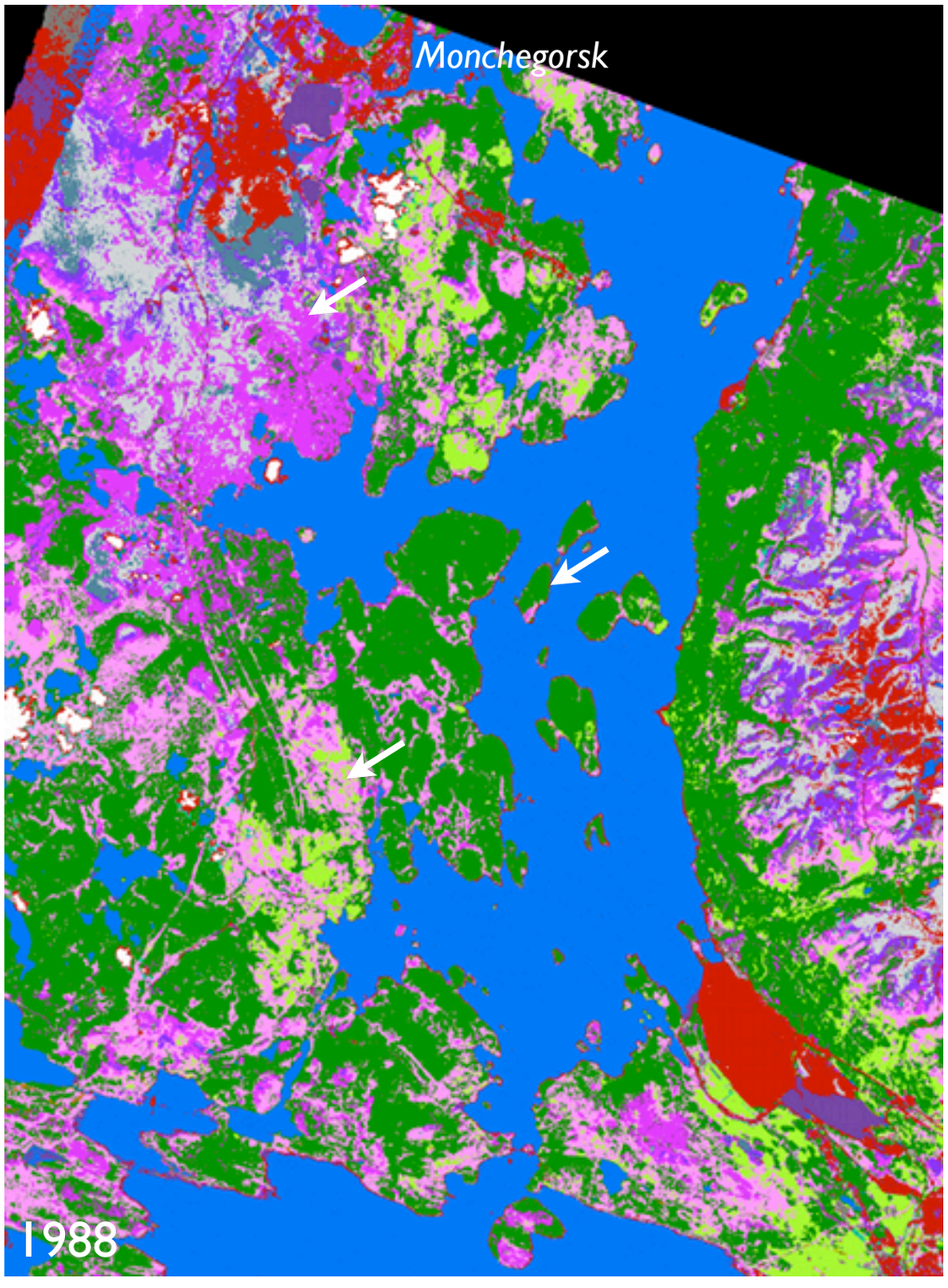


Results of automated classification for
L5188012_01219860728, 28 July 1986

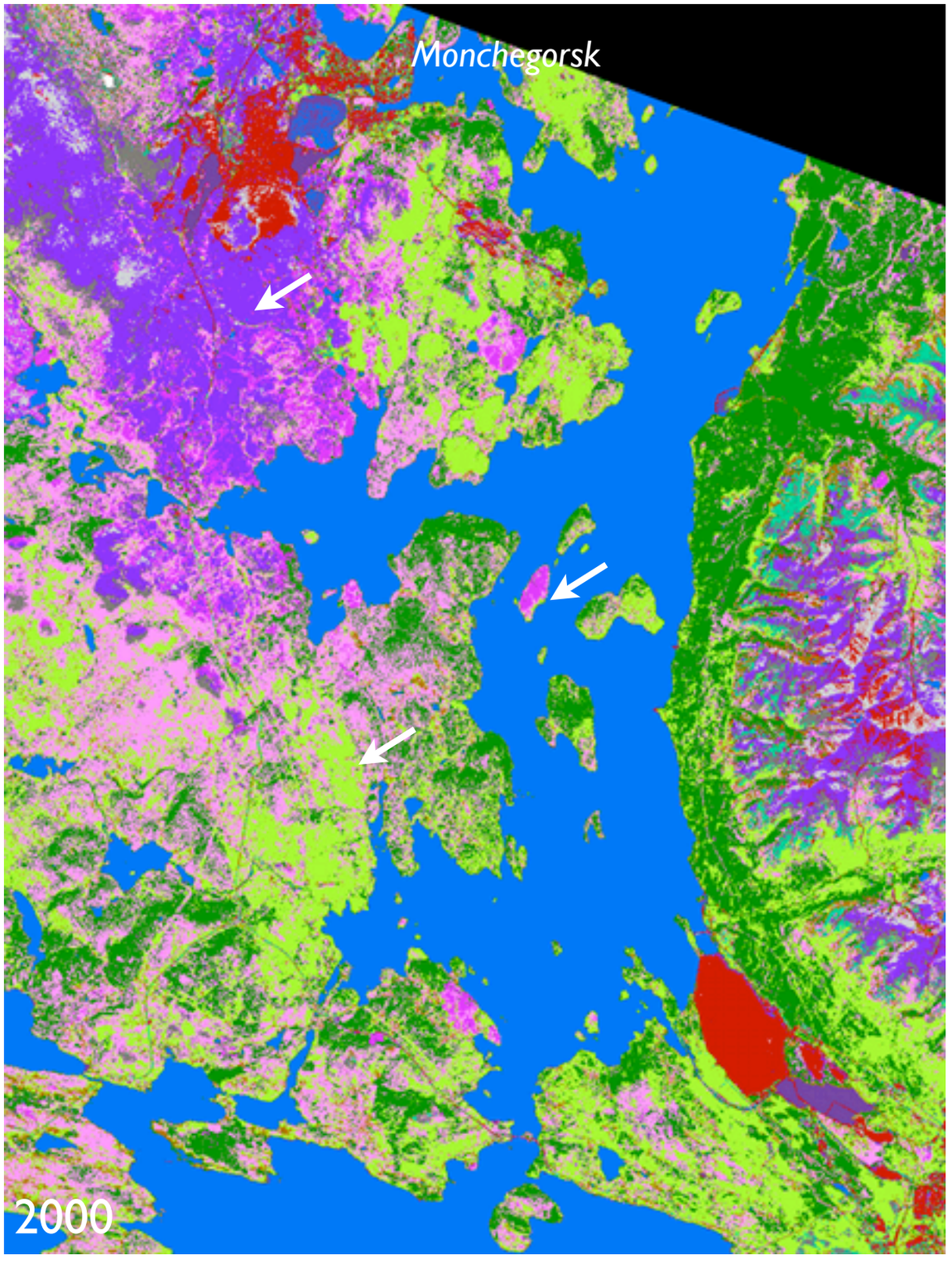


Results of automated classification for
Landsat LT41860131988193XXX03, 11 July 1988

Results: monitoring ecosystem 1988-2000

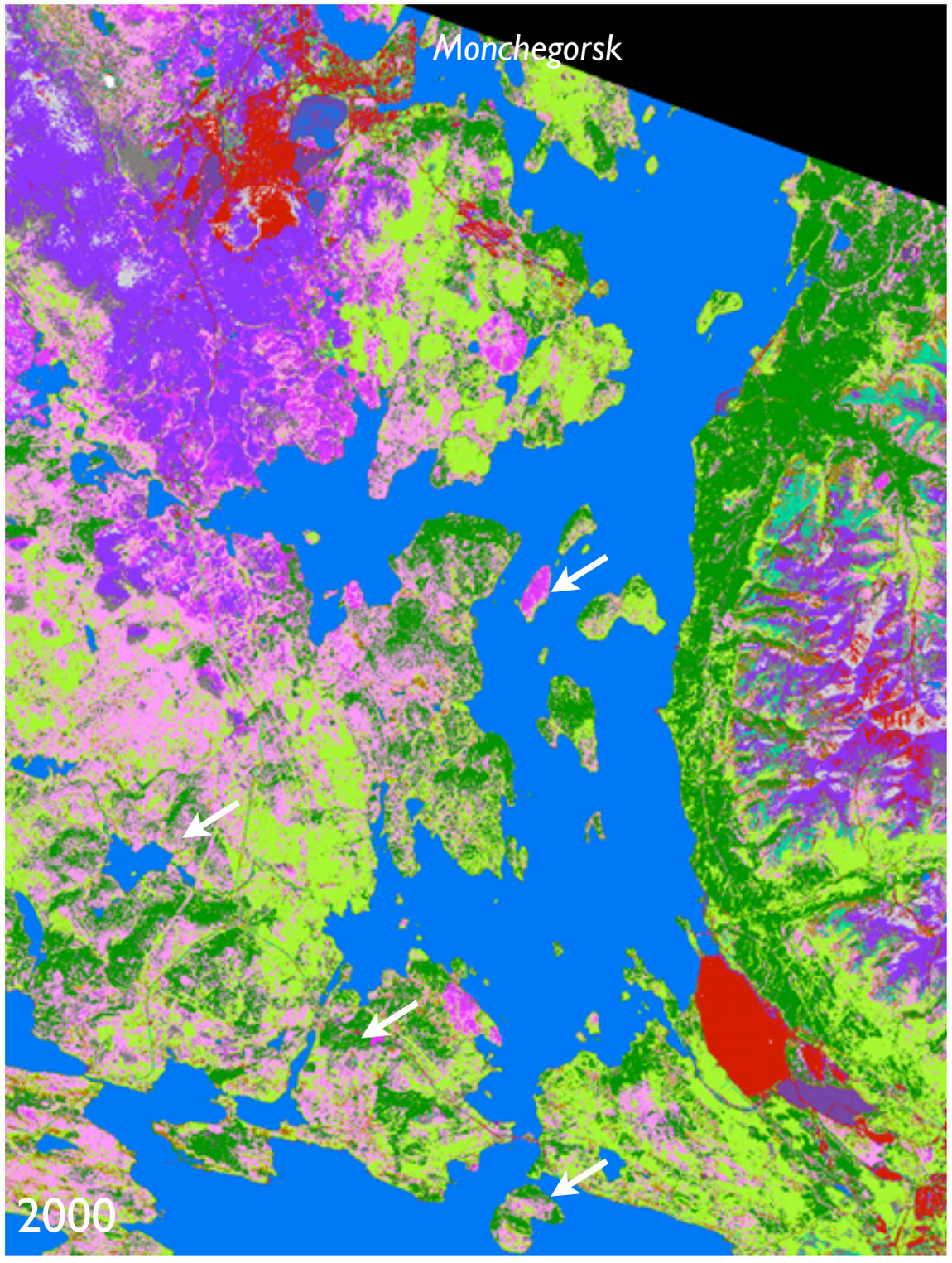


Results of automated classification for
Landsat LT41860131988193XXX03, 11 July 1988

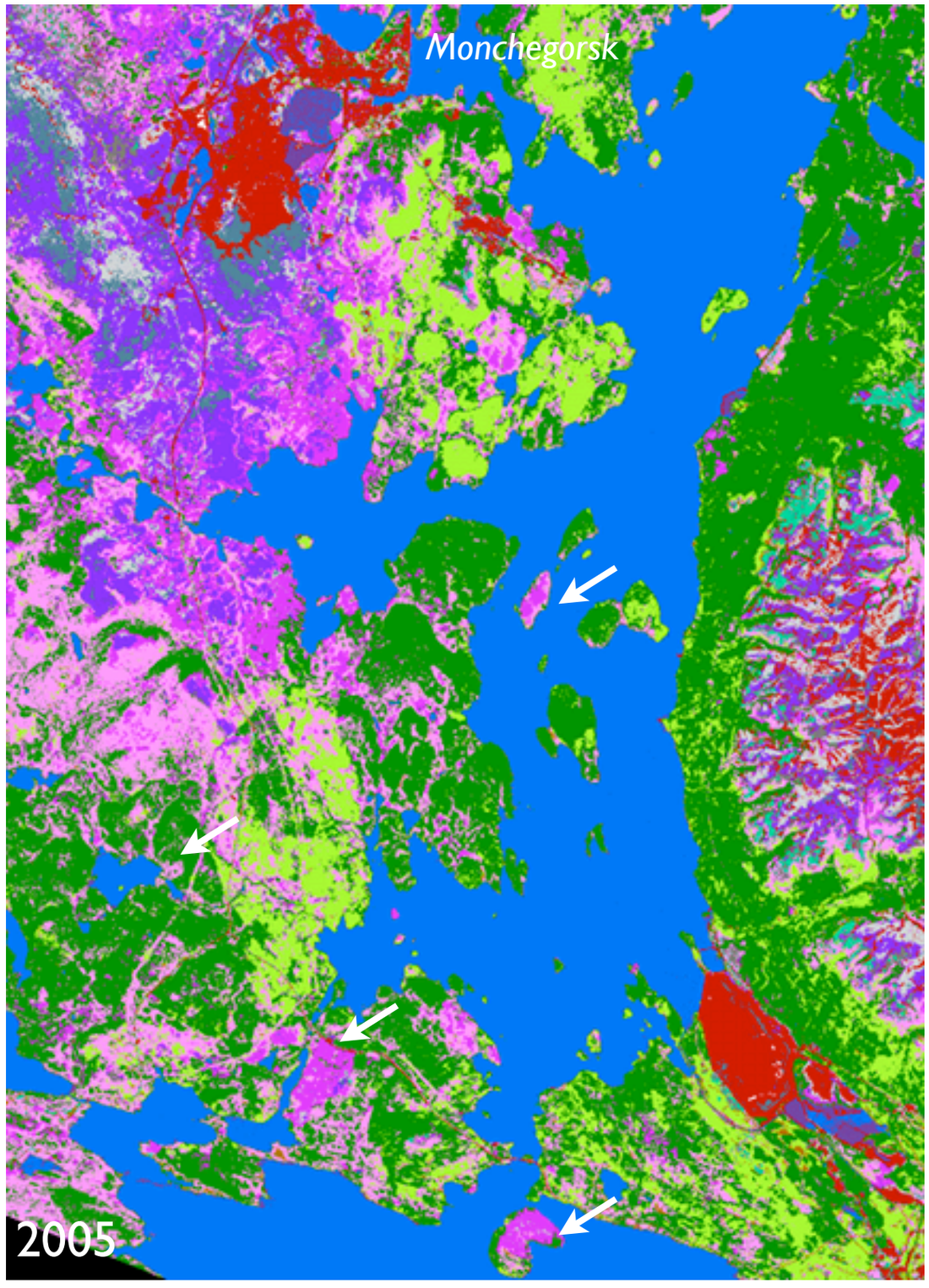


Results of automated classification for
Landsat elp186r013_7t20000728, 28 July 2000

Results: monitoring ecosystem 2000-2005



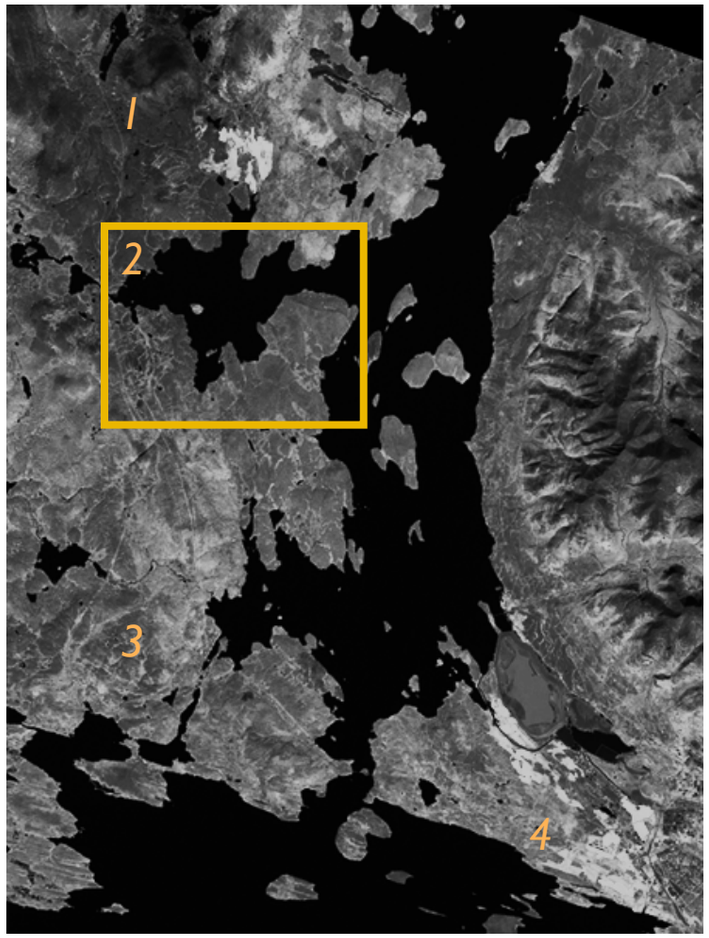
Results of automated classification for
Landsat elp186r013_7t20000728, 28 July 2000



Results of automated classification for
Landsat LE71860132005191ASN00, 10 July 2005

Local temporal monitoring of ecosystem changes (1)

Landsat elp186r013_7t20000728 Zone 4



Photos by author, 2002-2004

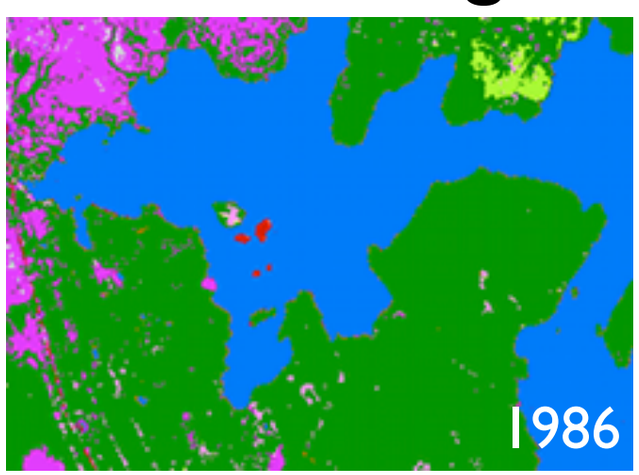
Technogenic barren

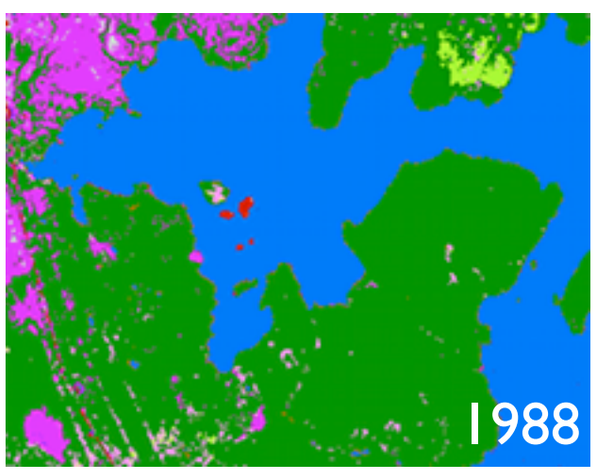
Moderately damaged

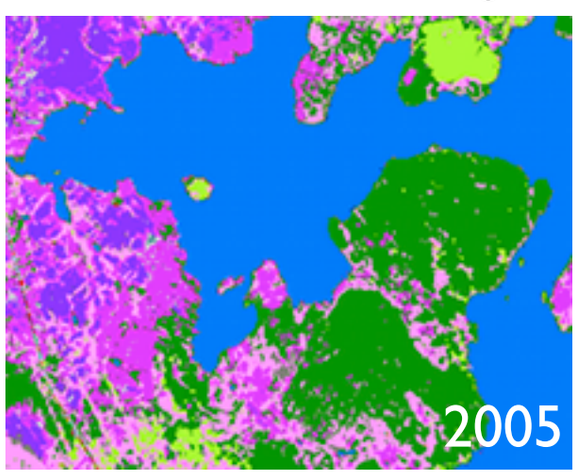
Severely damaged

Slightly damaged / undamaged

Degradation & restoration of forest vegetation

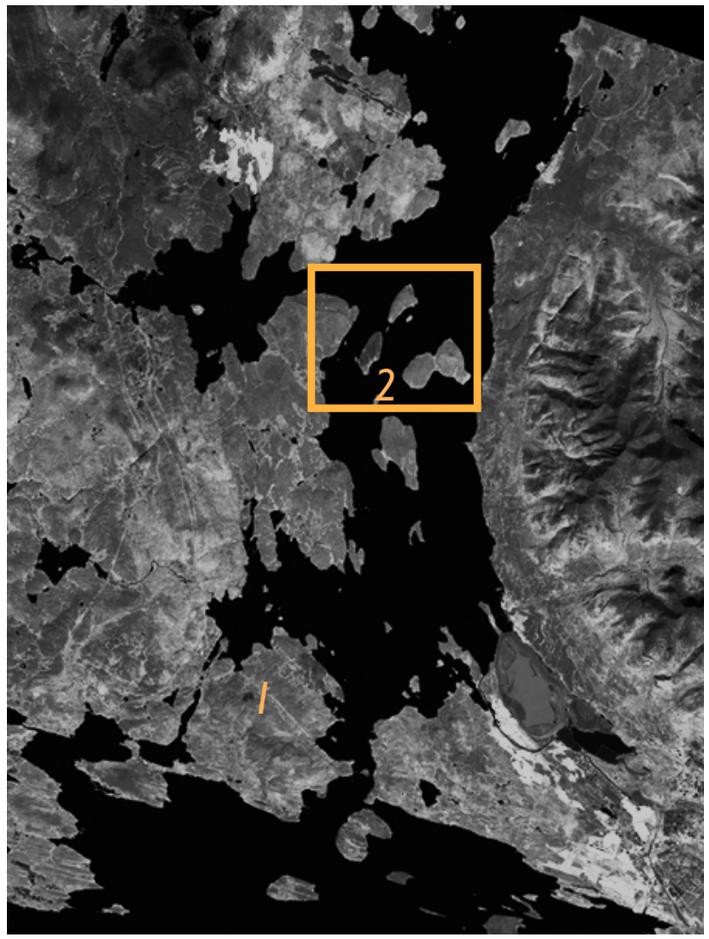






Local temporal monitoring of ecosystem changes (2)

Landsat elp186r013_7t20000728 Zone 4

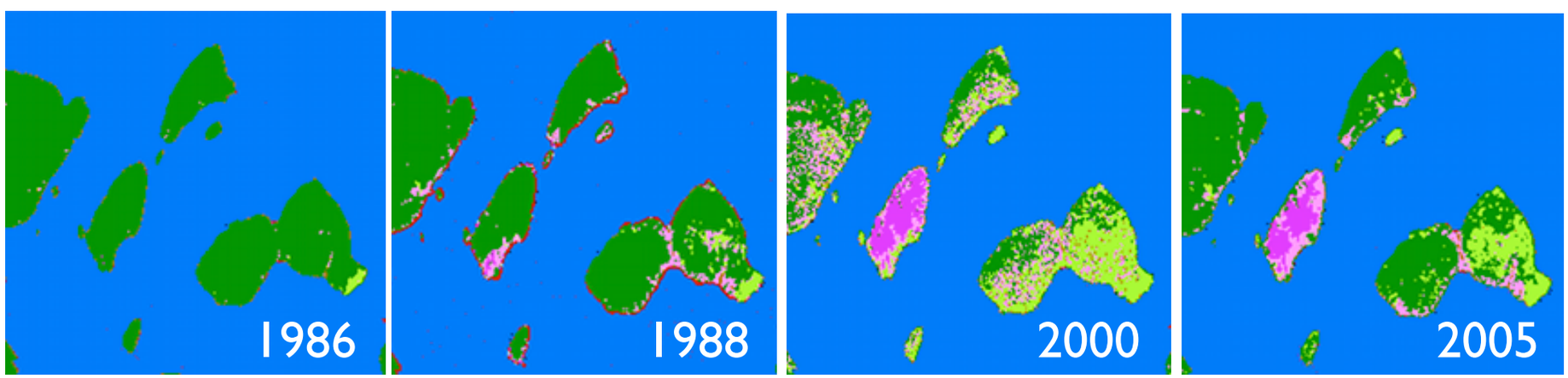


New burnt areas

First stage of succession; restoration by grass

Photos by author, 2002-2004

Restoration of burnt areas and new fires



Thank you

Photos by the authors and
A. Miheeva, 2004, 2007